Fast Infrared Sub-Flares From GRS 1915+105

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Abstract. We report the discovery of fast ($\sim$ 100 sec) 2.2 μm flares from the microquasar GRS 1915+105, which are superimposed on longer ($\sim$ 30 min), brighter flares corresponding to episodes of jet formation. The number and strength of the sub-flares in each bright flare varies, and does not seem to correlate in any obvious way with the underlying light curve or with changes in the X-ray emission. However, the fact that these sub-flares only occur in tandem with the larger flares indicates that they might be related to the jet ejection process.

1. Introduction

Simultaneous X-ray and infrared light curves of the microquasar GRS 1915+105 were obtained on August 14, 1997 [1], one of the first observations showing the disk-jet interaction in this source (Figure 1). GRS 1915+105 exhibited quasi-regular flaring behavior in the infrared during the course of these observations (interpreted as synchrotron emission from ejected plasma), and the flares were seen to correlate with changes in the X-ray emission (interpreted as emptying and refilling of the system's inner accretion disk).

Smaller amplitude variability, on faster timescales, was also observed in some of the infrared flares. In this contribution, we have reanalyzed the original data (obtaining higher signal-to-noise photometry than previously presented) and identified all such "sub-flares" above a given detection threshold, in an attempt to characterize this previously unknown phenomenon.

2. Data Analysis

The infrared data presented here consist of observations of GRS 1915+105 and a nearby field star, which we used for calibration purposes. We detected sub-flares using the following procedure:

- At each time step, we added a 2% systematic error to the measurement errors from the photometry. This was chosen in order to make the errors for the calibration star roughly match those determined from the variability in its light curve.
- We then ran the GRS 1915+105 and calibration star light curves through a high pass filter to remove all frequencies lower than $\sim$ 1/(500 sec).
- We searched for sub-flares centered at each point in the light curve on timescales ranging from 25 to 200 seconds and identified those with reduced chi-squared above a threshold value. The threshold was chosen to make the probability of obtaining one false detection across the entire light

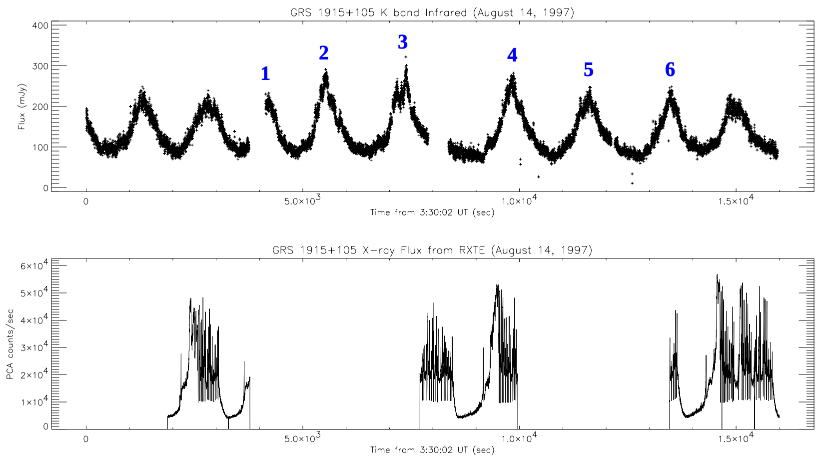

Figure 1. Light curves of GRS 1915+105 on August 14, 1997 UT (Eikenberry et al. 1998). The data in the top panel were taken in K-band (2.2 microns) using the Palomar 5-meter telescope and have been dereddened by 3.3 magnitudes. The data in the bottom panel were taken using the Proportional Counter Array (PCA) on the Rossi X-ray Timing Explorer (RXTE). Both light curves have time resolution of one second. The numbered infrared flares correspond to those shown in Figure 2.

curve $<\sim 1\%$, and also to ensure that any atmospheric variability too weak to observe in the (fainter) calibration star did not lead to any false detections of sub-flares in GRS 1915+105.

– We eliminated GRS 1915+105 sub-flares that correlated in time with calibration star flares, assuming these were due to atmospheric variability.

3. Discussion

The sub-flares we detected are shown in Figure 2. They have typical rise times of 40 to 100 seconds (with a few longer) and typical amplitudes of 25 to 70 mJy. The most important point about the sub-flares is that they are all superimposed on larger flares, indicating a possible relationship to the jet. Some of the large flares are multiple-peaked (2,3), with several strong sub-flares superimposed on them, while other large flares only have one peak (1,6), but it is sharp enough to be detected as a sub-flare by our algorithm.

There is no obvious correlation between the properties of the main flare and the number and strength of sub-flares superimposed on it. The X-ray coverage of the sub-flare detections is poor, but in one case for which they overlap (4), a faint sub-flare is detected at the beginning of the main flare, indicating a possible connection to the X-ray "spike" which marks the beginning of the jet ejection. Two other flares (2,3) also show evidence for a faint sub-flare near the beginning of the main flare. Taken together, this suggests that these sub-flares originate near the accretion disk and might be associated with the jet formation process.

Acknowledgments

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References

1. Eikenberry, S.S., Matthews, K., Morgan, E.H., Remillard, R.A. & Nelson, R.W., 1998, ApJ, **494**, L61.

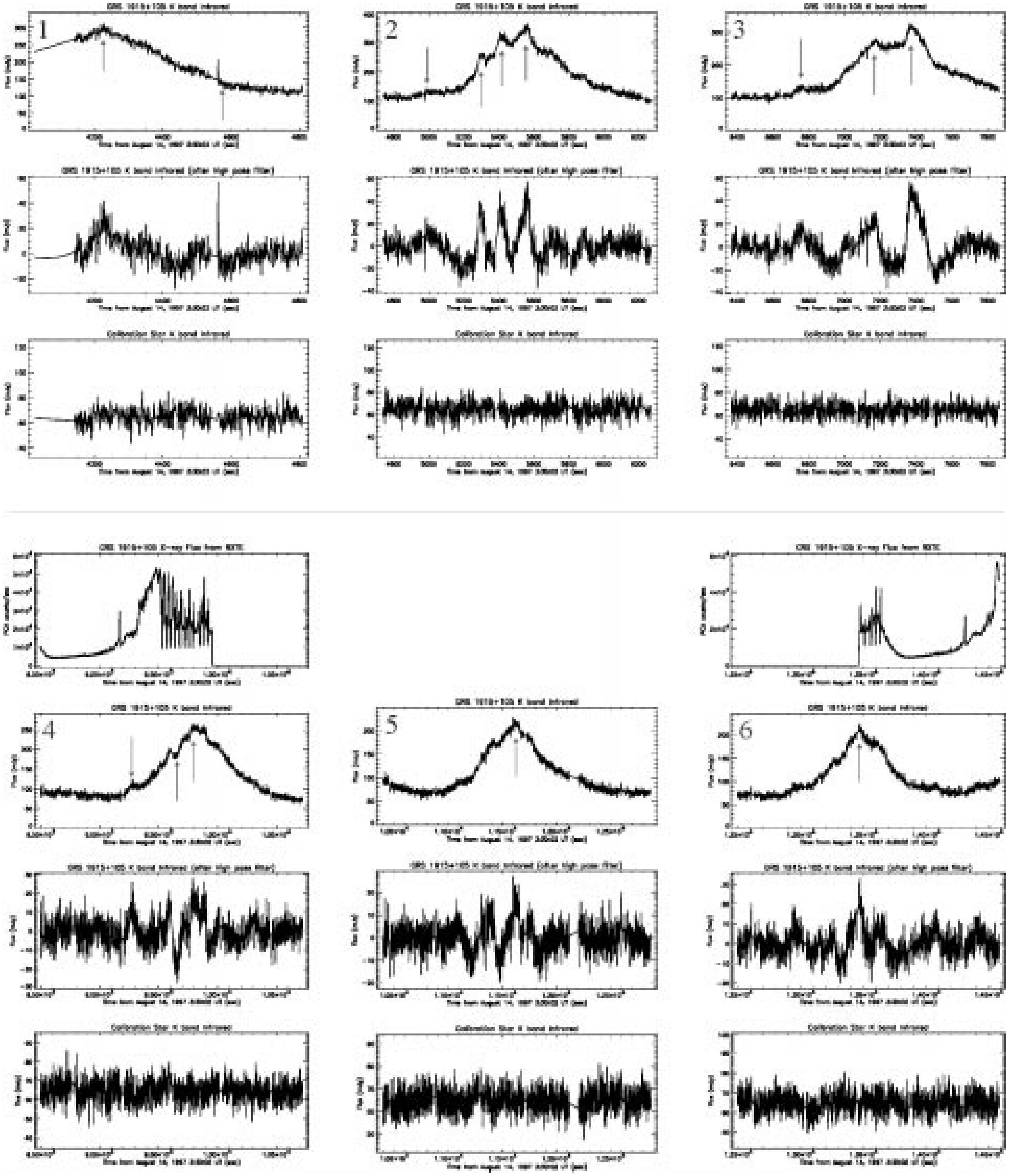

Figure 2. The reanalyzed data from Figure 1, showing the six infrared flares in which sub-flares were detected. In each case, the numbered panel shows the reanalyzed light curve from Figure 1, with arrows marking each statistically significant sub-flare. The next panel down shows the light curve after application of a high pass filter to remove all frequencies lower than $\sim 1/(500$ sec). The bottom panel shows the light curve of a field star near GRS 1915+105, which we used to calibrate variation due to atmospheric effects. In (4) and (6), the top panel shows the X-ray light curve from Figure 1 at the time corresponding to the sub-flaring behavior.